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PROGRESS REPORT No. 1

(Period from July 19, 1973 to March 31, 1974)

FIELD STUDY ON THE PRESIDENT COSTA E SILVA BRIDGE

(STEEL STRUCTURE)

by

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This report is intended to supply information on the progress of the program to date and to give a brief introductory description of the instrumentation used and of some of the results obtained. A comprehensive description will be provided in the final project report.

1. PURPOSE AND PROGRESS

The instrumentation of the steel portion of the President Costa e Silva Bridge was to serve the following three principal functions:

- 1) Monitoring of some selected stress points during construction for deviations from the computed values. Occurrence of an alarming deviation would have indicated a need for some corrective measures.
- 2) Extensive data collection on the stress and temperature conditions during construction and after completion for a detailed evaluation of the accuracy of the assumptions used in the design of the bridge.
- 3) Acquisition of information on the stress history for the orthotropic deck under regular traffic conditions. This should give some insight into the possibility of fatigue damage.

Several aspects of this instrumentation program are unique and appear for the first time in the world. These are: (1) Taking readings on a bridge during construction for the purpose of checking the safety of the structure, (2) the test load program on the completed bridge, (3) the extent and complexity of the total strain instrumentation, and (4) the use of an extensive instrumentation for a comprehensive temperature study during and after construction. Of direct service to the safety of the bridge are the strain readings during construction and the orthotropic deck studies.

Timewise, the program of study was planned to be carried out in the three phases described in the proposal (and in the contract) as shown in the time schedule of Fig. 1. Phase I (Erection Stresses) and a portion of Phase II (Studies on the Completed Bridge) have been completed. The remainder of Phase II and Phase III (Data Reduction and Report Preparation) are scheduled for the future.

In parallel to the subdivision by Phases, Exhibit A of the proposal lists eight specific items with tentative dates. The first five of the items have been completed (in Fig. 1 this covers all Phases up to and including Phase II.C.1). A summary of this work, punctuated by the trips of Lehigh University personnel to Rio de Janeiro, is as follows.

Professor J. W. Fisher was in Rio during July 13 to 20, 1973, and completed the research proposal in accordance with the needs of ECEX and taking into consideration the actual field conditions. Basic design of the instrumentation and the making of arrangements for the needed supplies and equipment were started on July 20 and carried out through August, 1973. (Item 1 of Exhibit A and the August '73 segment of Fig. 1).

On September 2, Professor Ostapenko and Mr. Sutherland made their first trip to Rio in order to instrument the Rio side span boxes. Prof. Ostapenko spent 10 days on the site and Mr. Sutherland remained to complete the instrumentation and preparations for the first study of stresses induced during construction. This activity is shown as Item 2 in Exhibit A and Phase I.B in Fig. 1.

Professor Ostapenko returned to Rio on October 1 so that measurements noted in Item 3 of Exhibit A could be taken. Readings were acquired on the cross sections at FB (floor beams) 17, 27, 42, 51, 57 as the North box of the Rio side span was transferred from its temporary construction supports to the center section used as a pontoon. Readings were also taken as the side span was moved from the pontoon to the pier lifting rings. A few mechanical gage readings were obtained on the South box during similar operations. All planned measurements were completed for Item 3 by October 14 and Prof. Ostapenko and Mr. Sutherland returned to Bethlehem.

Mr. Sutherland went to Rio on November 14 and Prof. Ostapenko on November 30 so that the measurements at the time of lifting the center span could be made (Item 4 of Exhibit A and Phase I.B of Fig. 1). The B&F data acquisition system was used to take readings on almost all 357 strain and temperature gages during this period. These measurements completed the planned data acquisition during construction of the bridge. Prof. Ostapenko and Mr. Sutherland returned to Bethlehem on December 15, 1973.

On February 15 Profs. Ostapenko and Daniels and Mr. Sutherland went to Rio to carry out the studies detailed in Item 5 of Exhibit A (Phase II.C of Fig. 1). These consisted of strain and temperature measurements on the completed structure. The principal test series covered the strain response of the structure under four arrangements of 21 17.5 ton loaded trucks as shown in Fig. 2. Measurements were also acquired on the orthotropic deck of the bridge near FB17 and 42. In addition to the controlled load studies, a distribution of strains and temperature was acquired for conditions during day time --- all other readings were made at night. The studies outlined under Item 5 of Exhibit A were thus completed and the project staff returned to Bethlehem between March 1 and 6, 1974.

During the periods when field work in Rio was not underway, most of the effort was spent on the detailed design of the instrumentation and the preparation of equipment for the next field test since each test required a somewhat different instrumentation scheme.

In addition to the on the spot monitoring of readings of the control gages during construction, some readings have been also analyzed in Bethlehem. However, most of the data reduction and analytical work are projected for the future.

2. INSTRUMENTATION AND SOME TEST RESULTS

The instrumentation used on the bridge can be subdivided into three types depending on the equipment used:

- 1) Electric-resistance strain and temperature gages over the whole cross section for static load conditions.
- 2) Mechanical and scratch gages.

- 3) Electric-resistance strain gages installed in the plate and stiffeners of the orthotropic deck for measuring transient stress variations under traffic loads.

(1) Electric-Resistance Strain and Temperature Gages

Electric-resistance strain and temperature gages were installed in the sections near FB (floor beam) 17, 27, 42, 51 and 57, as shown in Fig. 3 by dashed lines. A sample of the positions of individual gages in a cross section is illustrated in Fig. 4 (FB 57). There are temperature gages (symbolized by triangles), longitudinal gages (circles) and three-gage rosettes (crosses). A number in an oval designates a cable, each cable serving two gages. A combined total for all five sections was 52 temperature and 305 strain gages (357 altogether).

A schematic layout of the cabling is shown in Fig. 3. The gages of the sections at FB17 and 27 of both boxes are connected to a switching panel at FB27 in the North box. Similarly, the gages of sections at FB42, 51 and 57 are connected to a switching panel at FB51. The cables from the switching panels go to the outside of the North box at FB51 and are connected to a data acquisition unit (B&F). The system shown was used when the center span was lifted in December 1973 and for the load tests in February 1974. It will be also used in the planned June-July temperature studies.

A somewhat different arrangement, with an outside connection between FB27 and 51, was used on the North box alone when it was transferred from the jetties to the pontoon and then from the pontoon to the pier rings in October 1973. A different data acquisition unit (Datran) was used for making readings in this case.

An example of the distribution of stress changes in the cross section at FB51 as the result of transferring the North box from the jetties to the pontoon is shown in Fig. 5. The measured stresses are shown by dots and filled in by solid lines. The theoretical stress change is indicated by dashed lines. The discrepancy between the two is quite minor, well within the margin of safety provided in design. An important qualitative deviation is the non-linear distribution of the actual stresses in the bottom flange plate. This is apparently the effect of shear lag, and a later theoretical analysis should show how accurately it can be taken into account.

(2) Mechanical and Scratch Gages

Mechanical and scratch gages allow establishing continuity between sets of readings by electric-resistance gages made at different times.

Targets for the mechanical gage were drilled at the sections instrumented for the strain gages. Each set was supplied with a temperature compensating bar. A number of thermocouples were also installed.

The scratch gages were installed at FB17, 27, 42, 57 and 87. They provided a continuous (albeit not as accurate as by other gages) record of the stress changes in the bridge during construction and under test loads. The scratch gages are intended to remain on the bridge for monitoring unexpected unusual loading conditions.

A continuous record of the stress changes as provided by the scratch gage from the bottom location at FB42 is shown in Fig. 6. Going from left to right, the first zig of the trace shows a total compression change in stress of $(-)2470 \text{ kg/cm}^2$ (from the initial computed tension of $(+)975 \text{ kg/cm}^2$) due to the transfer from the jetties to the pontoon. The vertical downward and the inclined upward zig-zag is the record of stress changes caused by the setting of the side span on the pier rings and the lifting of the center span (pontoon) out of the water. The small amplitude zig-zag line which follows gives stresses produced by heavy loads on the bridge. The last two zigs are due to the positioning of the test loads. However, the preceeding ones escape a ready explanation, although it is probable that they were produced by the paving machine in its passages across the span.

(3) Orthotropic Deck Gages

A total of 68 strain gages were installed on the orthotropic deck in the North box near FB17 and 42 as indicated in Fig. 3.

Static and dynamic measurements were also acquired from these strain gages. The static measurements were taken under the truck load arrangements of the principal test series (Fig. 2). The dynamic stresses of some of the gages were measured using an oscillograph recorder while a single truck traversed the span several times in prescribed lanes.

These measurements were required in order to plan for the more extensive measurements to be taken during Phase II of the work (Fig. 1, Item 6).

(4) Other Observations

Monitoring of readings during the construction stages showed that there was an acceptable agreement between the measured and design stresses at the points checked. Thus, no concern arose for the safety of the structure.

Additional input for the analysis of the readings has been provided by the Supervision (Howard, Needles, Tammen & Bergendoff, Inc., Rio) in the form of survey data taken at various construction stages.

3. PLANNED WORK AND GENERAL TIME SCHEDULE

For the next six months the work will consist of the completion of Phase II (Studies on the Completed Bridge) by June-July, 1974 and concentration on Phase III (Data Reduction and Report Preparation). In the progress schedule of Fig. 1 this is indicated by the period from April till September 1974.

The immediate effort will be on the preparation for taking readings on the bridge under regular traffic in June-July, 1974 (Item 6 of Exhibit A). There are two parts to this.

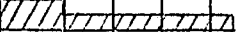





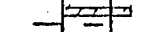



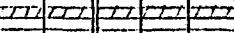
One is the acquisition of comprehensive stress history measurements on the plate and stiffeners of the orthotropic deck under normal traffic with particular attention to the truck flow. This data will permit a detailed evaluation of the behavior of the orthotropic deck under service load conditions. These studies will be then coupled with traffic projections so that potential cumulative fatigue damage can be assessed.

The second part is the temperature study to determine the instantaneous and varying thermal stresses produced by a quickly rising sun in the morning and the conditions in the early afternoon. Several sets of readings on all temperature and some selected strain gages will be taken in quick succession to establish a temperature-strain-time relationship. It is the first time that such a study is being done anywhere on a bridge. (Since these readings require considerable rearrangement of the switching systems and, thus, time for preparation, they could not be taken in February).

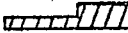
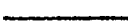
The primary effort for this period will be on the reduction and analysis of data acquired to date. A major activity will be the preparation of suitable computer programs for processing the data. Attention will be focused on the readings made during bridge erection (Items 3 and 4 of Exhibit A) and during the static load tests in February.

Fig.1 PROJECT PROGRESS SCHEDULE

Progress to
March 31, 1974

RESEARCH PHASE	ITEM*	1973					1974												1975							Est. % Compl.
		A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	
I ERECTION STRESSES																										
A. PLANNING & PREPARATION	1																									100
B. INSTRUMENTATION & MEASUREMENTS	2, 3 & 4																									100
II COMPLETED BRIDGE																										
A. PLANNING & PREPARATION	1																									90
B. INSTRUMENTATION	2, 3 4, 5																									90
C. STRESS MEAS.																										
1. Controlled Load, Temp.	5																									100
2. Normal Traffic & Temp.	6																									0
III A. DATA REDUCTION	7																									10
B. ANALYSIS	7, 8																									5
C. REPORT PREPARATION	8																									5
OVERALL COMPLETION		3	8	11	16	19	22	28	32	36	40	45	50	55	60	65	70	75	80	84	88	92	96	98	100	32

* Items in Exhibit A of Proposal

 Actual Effort Planned

P - Progress Report

F - Final Report

(Precisa de 21 caminhões, 17,5T cada um)

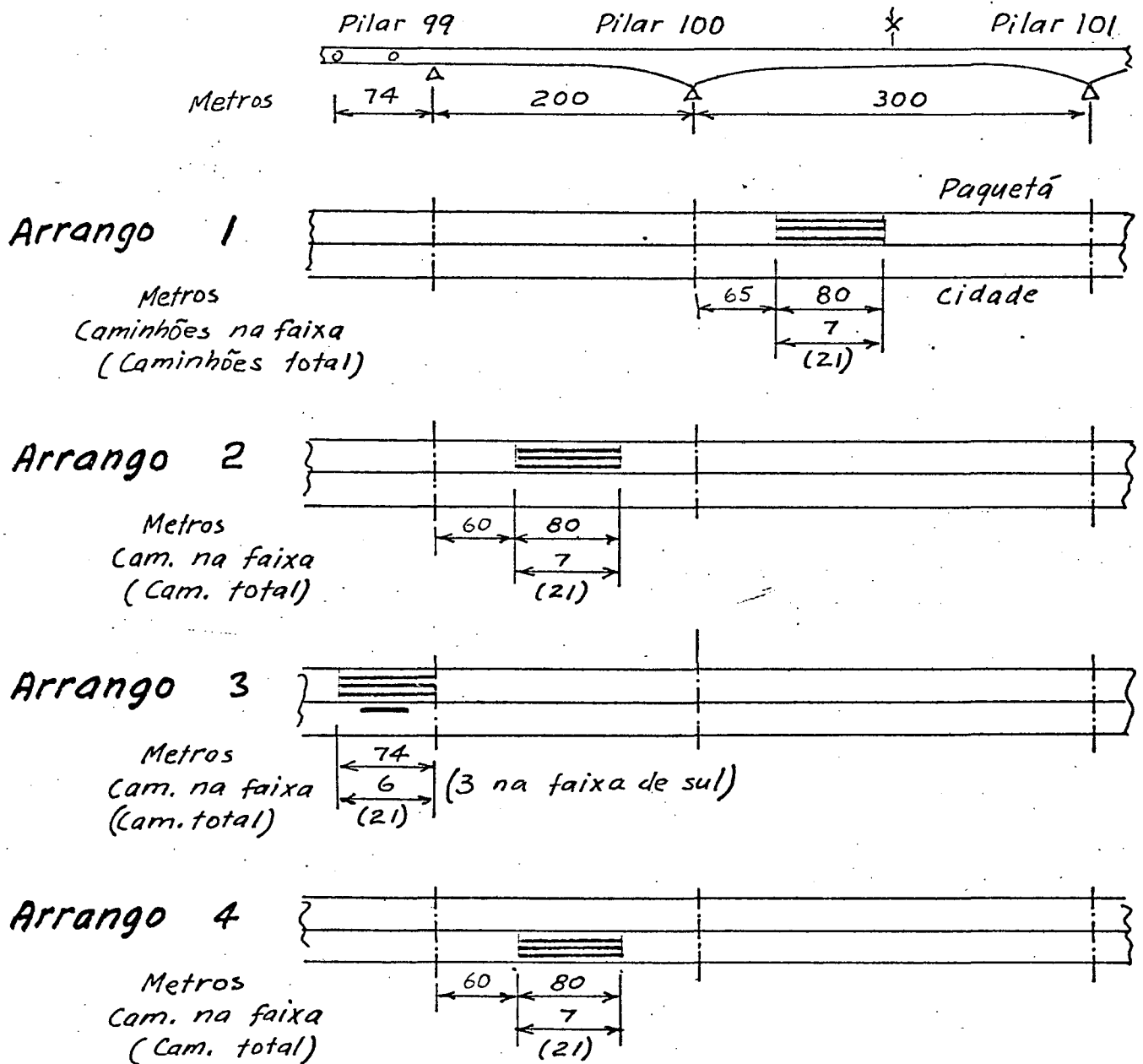


Fig.2 Test Load Arrangements

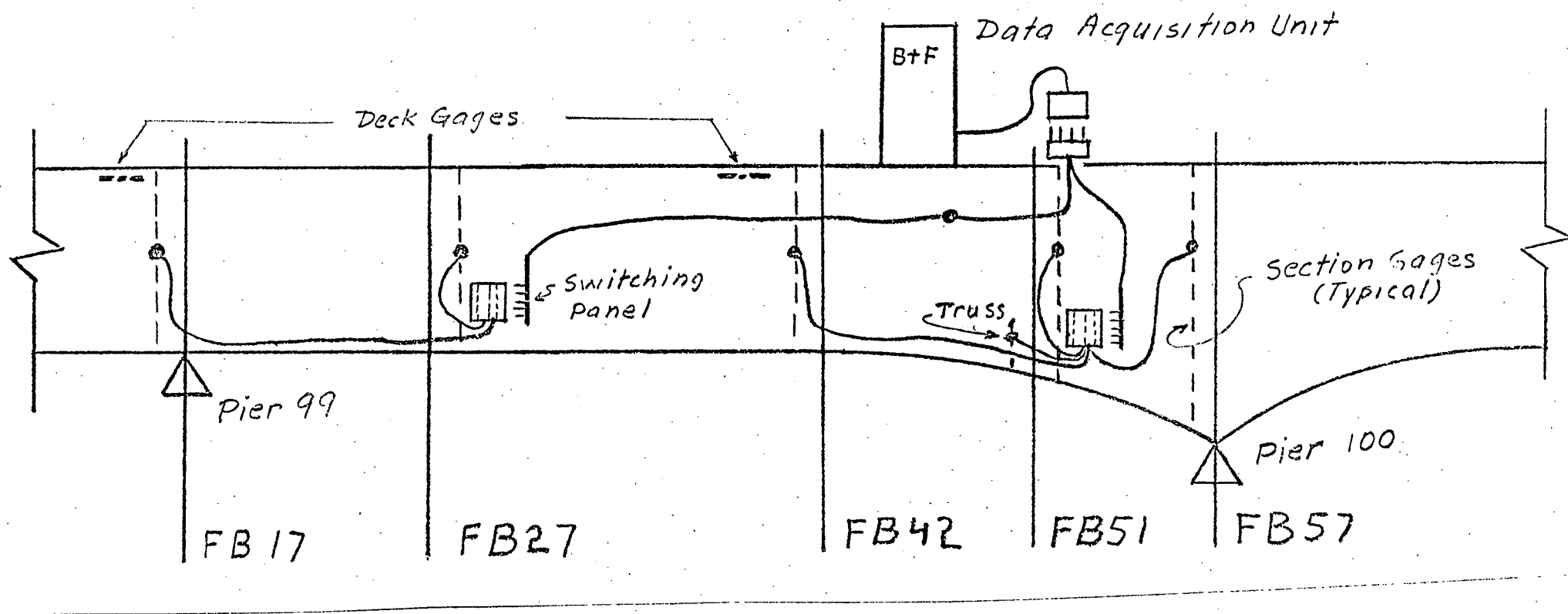


Fig.3 Instrumented Sections (Electric-resistance Gages)
and Arrangement of Cables and Equipment

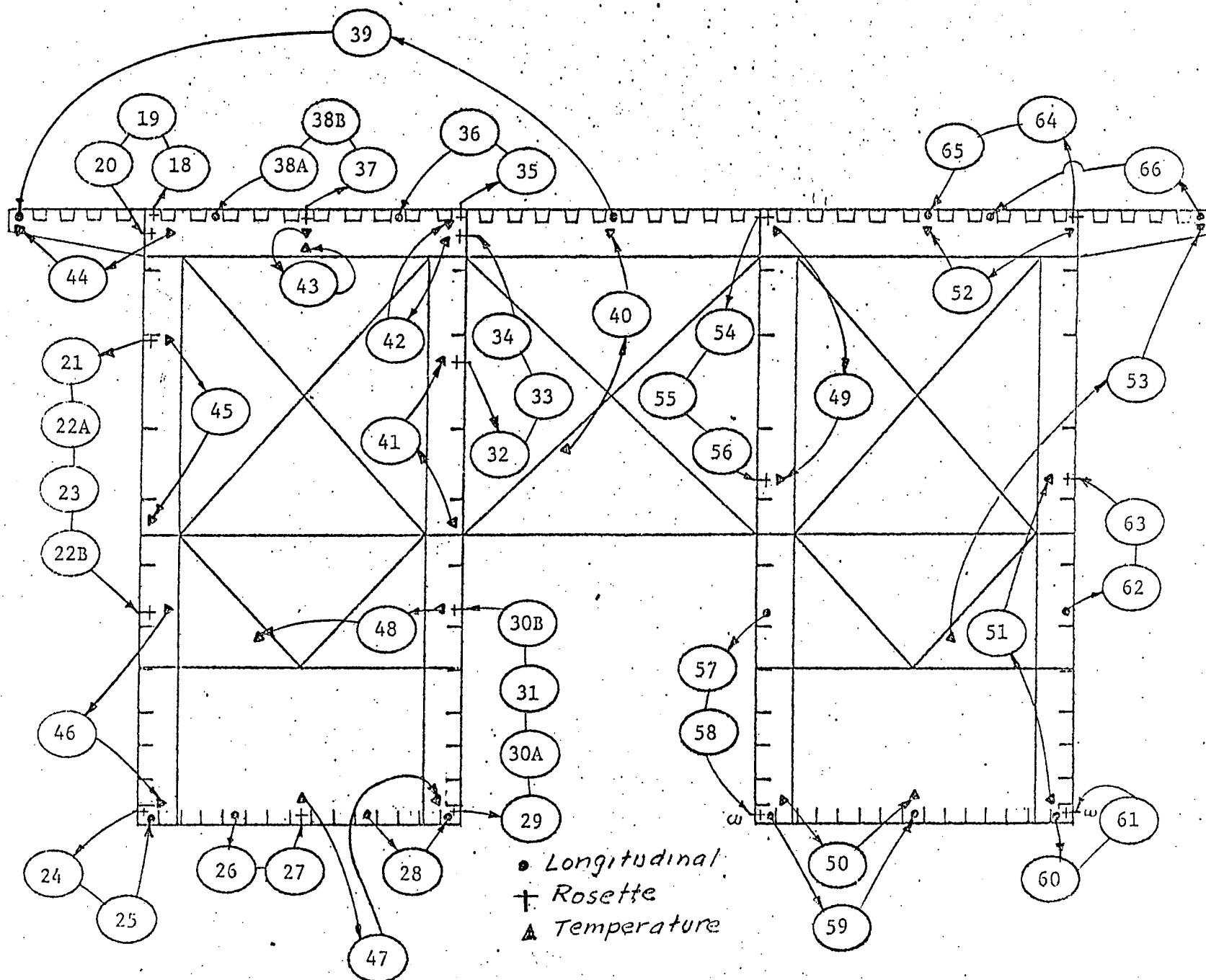


Fig.4 Strain and Temperature Gages at FB57

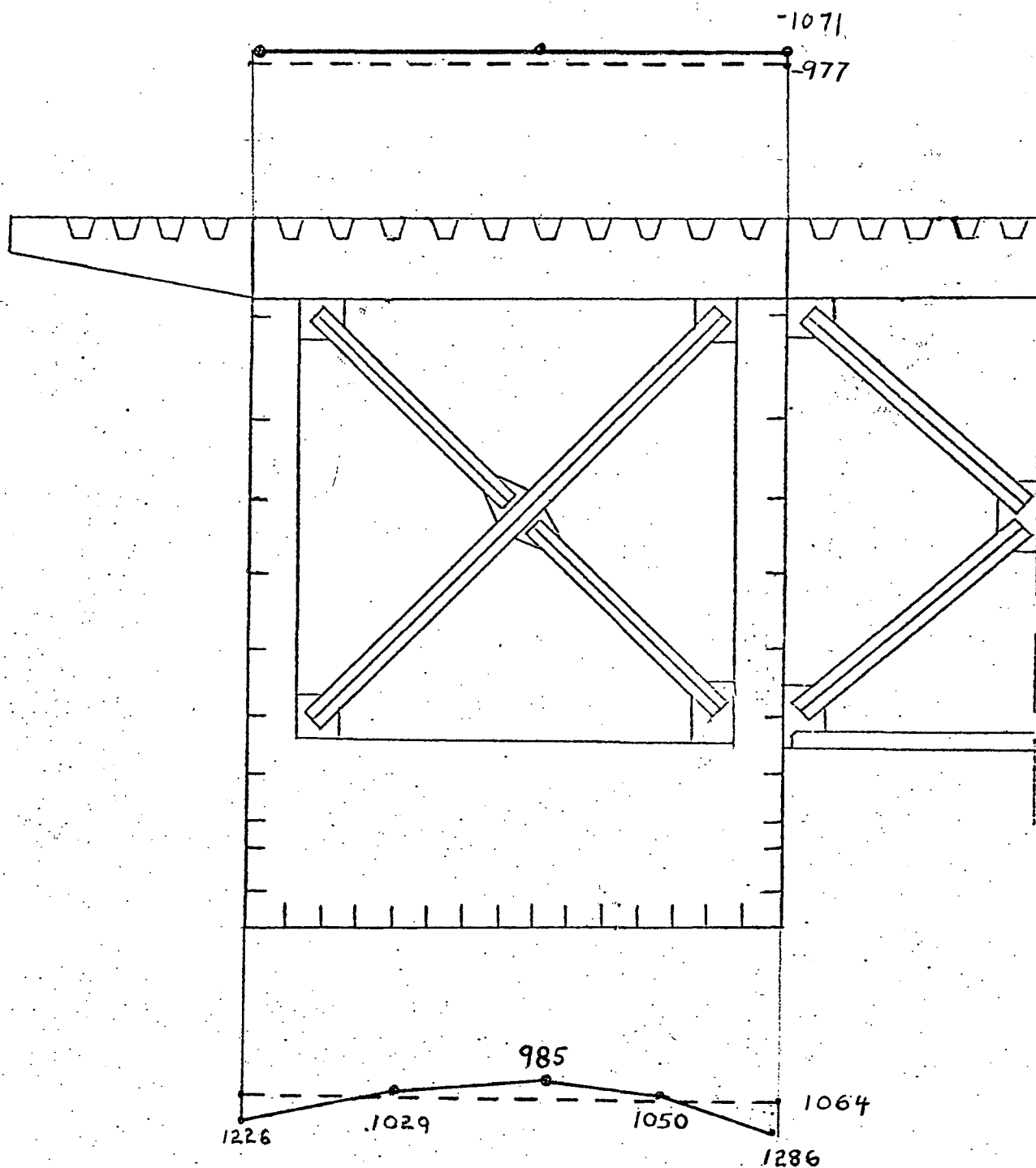
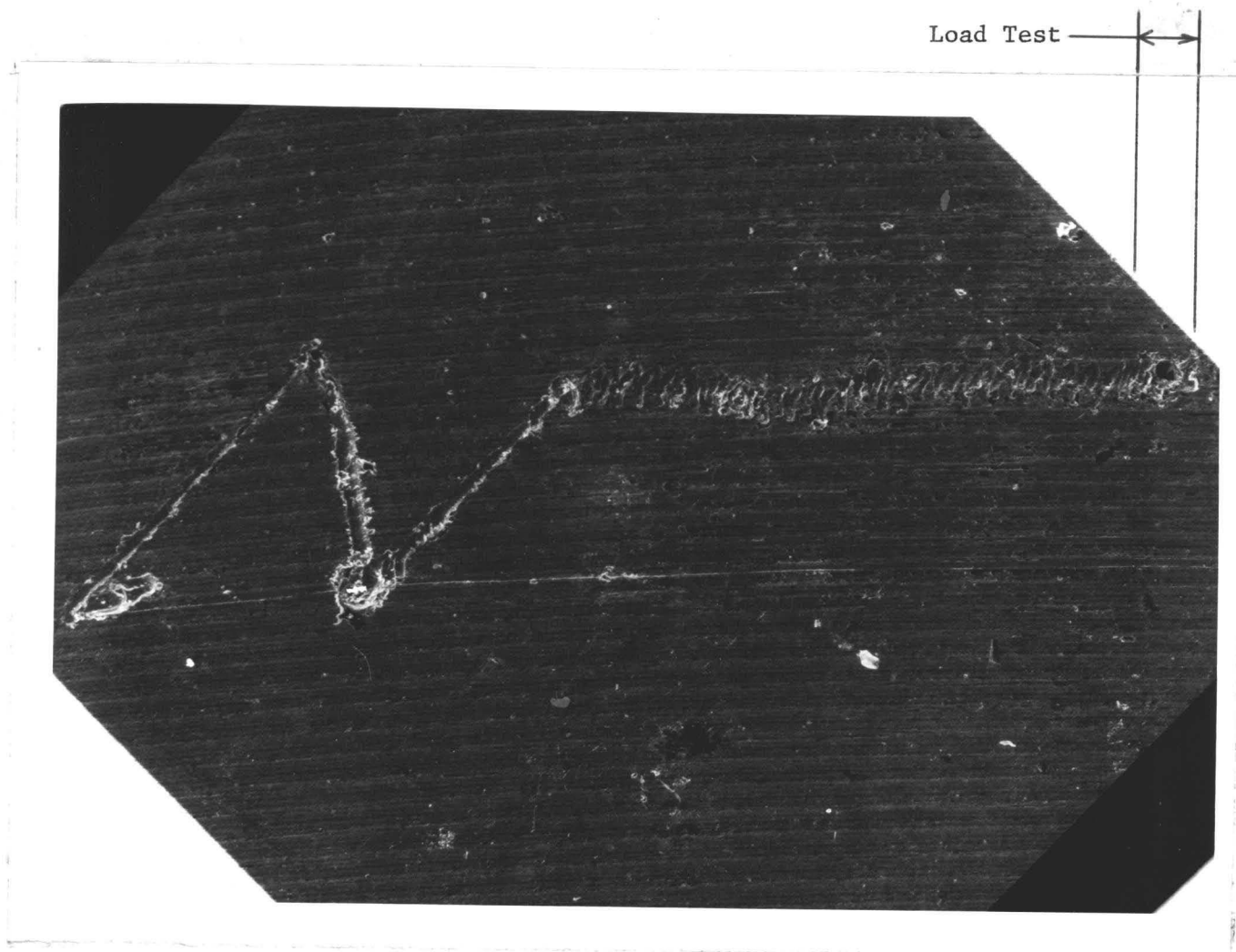


Fig.5 Flange Stresses at FB51
(Transfer from Pontoon to Pier)

SCALE: 1" = 1000 kg/cm²

--- THEORY

— EXPERIMENTAL



Magnification: 106 X

Gage Length = 12 in. = 30.5 cm.

Fig. 6 Scratch Gage Trace at FB42 (Bottom)